Status of:
Molten Carbonate Fuel Cells

Dr. Robert J. Remick,
Colorado Fuel Cell Center
May 31, 2006

CFCC
Colorado Fuel Cell Center

Commercial message

Colorado Fuel Cell Center

The CFCC is located in the General Research Lab (GRL) on the Colorado School of Mines Campus.

CFCC
Colorado Fuel Cell Center

Three-Fold Mission

- Provide state leadership in fuel cell technology development,
- Provide opportunities for public education on the benefits of fuel cells,
- Assist in the formation of strategic alliances between fuel cell developers and local businesses and universities.

CFCC
Colorado Fuel Cell Center

Now back to our program.

Molten Carbonate Fuel Cells

Colorado Fuel Cell Center

MCFC Status in a Nutshell- "You can buy 'em"

- Manufactured by
  - FuelCell Energy in Danbury, CT and by
  - MTU in Ottobrunn, Germany
- Typical DFC 300 installation costs about $1.2 million - $4600/kW
- Costs may approach $3000/kW in megawatt size plants (DFC 1500)

CFCC
Colorado Fuel Cell Center

MCFC Basics

- Operate at 600 to 650°C (~1200°F)
- Lithium and potassium carbonates
- Nickel based electrodes
- Stainless steel separators and hardware
- Low power density → stationary only
- Not compatible with pure H_2 fuels

CFCC
Colorado Fuel Cell Center

MCFC Chemistry

- Must have carbon dioxide in both fuel and oxidant.
- Needed on oxidant side to form CO_3^{2-}
  - $\frac{1}{2}\ O_2 + CO_2 + 2\ \text{electrons} \rightarrow CO_3^{2-}$
- Needed on fuel side to prevent decomposition of the electrolyte.
  - $H_2O + K_2CO_3 \leftrightarrow 2\ KOH + CO_2$

CFCC
Colorado Fuel Cell Center

MCFC Require HC_x Fuels

- The DFC 300 and DFC 1500 require methane in the fuel stream.
- Methane is reformed internally to produce hydrogen and remove heat.
  - $2\ H_2O\ +\ CH_4\ +$ heat $\rightarrow\ 4\ H_2\ +\ CO_2$
- The hydrogen is then used to make power. $H_2 + CO_3^{2-} \rightarrow\ H_2O + CO_2 +$ elec.

CFCC
Colorado Fuel Cell Center

High temperature technologies push efficiency to higher limits

FuelCell Energy
DFC-300

Uses

1920 SCF/hr NG

Produces

250 kW electric (47%)

300,000 Btu/hr (16%)
steam at 640°F

Use of co-generated heat saves 300 SCF/hr in additional fuel purchases.

CFCC
Colorado Fuel Cell Center

Bad Press

- Westerville, Ohio shuts down fuel cell*
  - "Officials say cell was a victim of rising natural gas costs and a costly maintenance contract."
  - Natural gas prices quoted as $12 MMSCF (we think they mean MMBtu) while local electric rates were 5.5¢/kW-hr

* *Columbus C.E.O.* Magazine, May 2006

CFCC
Colorado Fuel Cell Center

Realities of high fuel prices

- Natural Gas Costs as ¢/kw-hr*
  - 1.5 ¢/kW-hr at $2 MMBtu
  - 3.1 ¢/kW-hr at $4 MMBtu
  - 6.1 ¢/kW-hr at $8 MMBtu
  - 7.7 ¢/kW-hr at $10 MMBtu
  - 9.2 ¢/kW-hr at $12 MMBtu

* Based on specifications for DFC 300

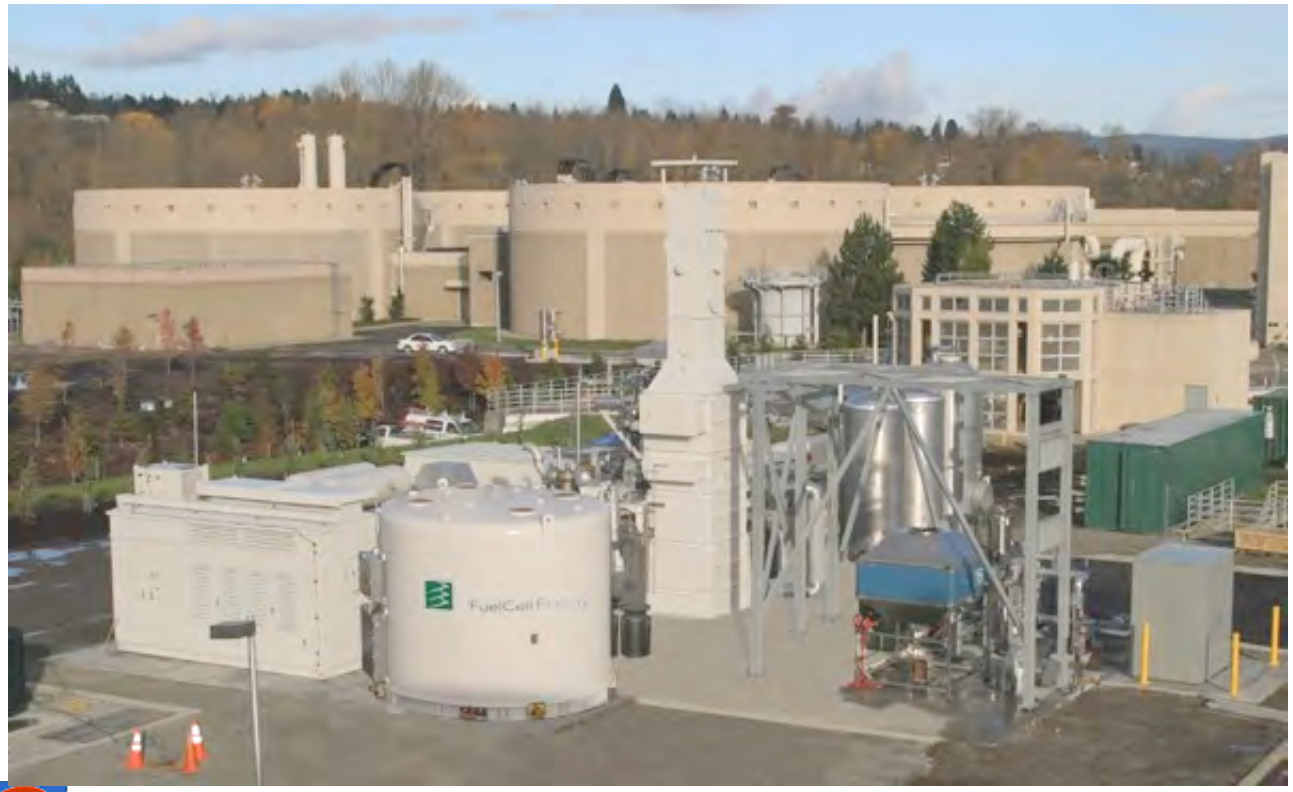
CFCC
Colorado Fuel Cell Center

But what if the fuel is free?

Colorado Fuel Cell Center

MCFC are Efficient for On-site Generation using Methane

FuelCellEnergy 1-megawatt power plant



Renton, WA, wastewater treatment plant

Colorado Fuel Cell Center

Current California MCFCs

- LADWP-Terminal Island, San Pedro
- LADWP-Main St., LA
- LADWP-Headquarters Building, LA
- El Estero Wastewater Treatment Plant, Santa Barbara
- Sierra Nevada Brewing Co., Chico, CA
- Sheraton San Diego Hotel & Marina
- California State University, Northridge

CFCC
Colorado Fuel Cell Center

Waste is Power

- MCFC have been demonstrated on:
  - Methane from landfills
  - Methane from sewage treatment plants
- Other alternatives for consideration
  - Methane from digestion of agricultural and food-processing wastes
  - Waste streams from production of biofuels

CFCC
Colorado Fuel Cell Center

R&D Challenges

- Identify viable waste streams
- Develop processing methods for maximizing methane production from agricultural and food processing wastes
- Improve performance and endurance
- Reduce manufacturing costs

CFCC
Colorado Fuel Cell Center